Distr.
LIMITED

A/CONF.184/BP/6
26 May 1998

ORIGINAL: ENGLISH

THIRD UNITED NATIONS CONFERENCE
ON THE EXPLORATION AND PEACEFUL USES OF OUTER SPACE

BASIC SPACE SCIENCE AND MICROGRAVITY RESEARCH AND THEIR BENEFITS

Background paper 6

The full list of the background papers:

1. The Earth and its environment in space
2. Disaster prediction, warning and mitigation
3. Management of Earth resources
4. Satellite navigation and location systems
5. Space communications and applications
6. Basic space science and microgravity research and their benefits
7. Commercial aspects of space exploration, including spin-off benefits
8. Information systems for research and applications
9. Small satellite missions
10. Education and training in space science and technology
11. Economic and societal benefits
12. Promotion of international cooperation

V.98-53856 (E)

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PREFACE

The General Assembly, in its resolution 52/56, agreed that the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) should be convened at the United Nations Office at Vienna from 19 to 30 July 1999 as a special session of the Committee on the Peaceful Uses of Outer Space, open to all Member States of the United Nations.

The primary objectives of UNISPACE III will be:

(a) To promote effective means of using space technology to assist in the solution of problems of regional or global significance;

(b) To strengthen the capabilities of Member States, in particular developing countries, to use the applications of space research for economic and cultural development.

Other objectives of UNISPACE III will be as follows:

(a) To provide developing countries with opportunities to define their needs for space applications for development purposes;

(b) To consider ways of expediting the use of space applications by Member States to promote sustainable development;

(c) To address the various issues related to education, training and technical assistance in space science and technology;

(d) To provide a valuable forum for a critical evaluation of space activities and to increase awareness among the general public regarding the benefits of space technology;

(e) To strengthen international cooperation in the development and use of space technology and its applications.

As one of the preparatory activities for UNISPACE III, the Office for Outer Space Affairs of the Secretariat has prepared a number of background papers to provide Member States participating in the Conference, as well as in the regional preparatory meetings, with information on the latest status and trends in the use of space-related technologies. The papers have been prepared on the basis of input provided by international organizations, space agencies and experts from all over the world. A set of 12 complementary background papers have been published and should be read collectively.

Member States, international organizations and space industries planning to attend UNISPACE III should consider the contents of the present paper, particularly in deciding on the composition of their delegation and in formulating contributions to the work of the Conference.

The present paper was prepared with the assistance of teams of experts from the European Space Agency (ESA) the Centre national d'études spatiales (CNES) of France, the Indian Institute for Astrophysics (IIA) the Indian Space Research Organization (ISRO), the International Space University (ISU), France, the Harvard-Smithsonian Center for Astrophysics (CFA), United States of America, the National Aeronautics and Space Administration (NASA), United States of America, The Planetary Society (TPS) United States of America, the United Nations Office at Vienna and the University of Science Malaysia (USM).

The assistance of M. J. Rycroft (International Space University, Strasbourg, France, and Cambridge University, United Kingdom of Great Britain and Northern Ireland) as technical editor of background papers 1 to 10 (A/CONF.184/BP/1-10) is gratefully acknowledged.

SUMMARY

The exploration of the universe from our solar system to the most remote parts represents one of the greatest intellectual adventures of humankind. The past four decades have witnessed a dramatic change in our views about the universe and its constituent parts, an ongoing revolution whose implications are still to be fully understood not only in the scientific context but also from a practical point of view. Such a widening of our horizons in such a short time is unprecedented in human history, with the possible exception of the time of Galileo. The great advance made by Galileo resulted from his use of a new optical device, the telescope, a huge step forward in the technology of his time. In a similar way the advances in technology characteristic of modern times have provided the basis for the discovery of completely new sets of phenomena that have radically modified our understanding of problems such as the formation and evolution of planets, stars, galaxies and the universe as a whole.

Images of the Earth taken from space and satellite studies of the global Earth system and global change have created a dramatically new perspective on the relationship between the inhabitants of Earth and their planet. Continuing studies of that relationship will improve understanding of how human activities may be affecting the health of the global environment.

Through telescopic images and robotic space probes, further details about the nine planets in the solar system, as well as its numerous moons, asteroids and comets, have become known. It has been discovered that many features of planet Earth are shared by other bodies of the solar system and thus the unique features of Earth that make possible its great diversity of life may be better appreciated.

The beginnings of the space age came at a crucial time in human history. For the first time humans now have the ability to alter the entire planet for better or for worse. The perspectives gained from space help us to understand the challenges facing civilization. Space age technologies in space exploration, remote sensing, communications and meteorology transcend economic and cultural borders. No longer can nations, or people, live in isolation. They must come together in education and global cooperation.

I. RATIONALE

1. Ever since humans learned to walk upright, they have looked at the sky and wondered. The sky has remained the same but not its meaning. At first it was thought of as a divinity to be feared and appeared, then as a phenomenon to be observed and utilized, and finally as a laboratory for studying nature. Through those stages, over the millennia, outer space has acquired a depth that mirrors the changing patterns of humankind's relationship with its cosmic environment.

2. Because of the spherical nature and rotation of the Earth, no country or observatory, no matter how well equipped, can observe the whole of the celestial sphere at all times. Also, cosmic phenomena can only be observed; adjustments cannot be made, nor can repeated observations of the same situation be obtained. Consequently, basic space science, unlike most laboratory science, is additive rather than exclusive, complementary rather than competitive. Although large-scale facilities, including space missions, must necessarily depend upon the initiative of highly industrialized countries, there is ample scope for regional and international collaboration and cooperation. Scientific instrumentation, engineering subsystems and data analysis are some of the areas where countries, observatories and academic groups can make valuable contributions. There is now a genuine desire and need for

international pooling of resources and ideas. Additionally, military technology and expenditure are being redirected towards basic space science.

3. Scientific inquiry into the nature of the universe beyond the Earth and exploration of the Sun's planetary system have, to date, been enterprises carried out by only a few countries. Perhaps for that reason, their relevance to the issues that are the focus of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) have not yet been given adequate attention or priority.

4. Clearly, the space science and exploration achievements of the last several years have captured the world's attention, interest and imagination. The people of Earth have shared the excitement of discovering and exploring the new worlds of our solar system and of looking beyond it into the cosmos. This era may prove to be as epochal as was the period of exploring the new worlds on Earth half a millennium ago.

5. Perhaps the primary benefits of this new age of discovery are in their impact on humanity's appreciation of its own global habitat in the context of the solar system and the universe beyond. The recognition that human beings are not at the centre of the universe but are part of a greater natural order represented a dramatic change in the attitude of people towards the world around them.

6. The new appreciation for the interdependence of human beings and their natural environment has inspired a vast expansion of interest in and study of the natural environment, including other planets, stars and the universe as a whole. In addition, the benefits of scientific discovery are quite tangible. Basic space science is a key to the prosperity of a nation and it is almost impossible to expect a country to have significant economic and social development without a sound educational and research base in the field of basic space science.

7. In the 40 years of the space age, scores of new worlds have been transformed from barely discernible points of light to whole new places of wonder. There is some evidence for past life on Mars, from indirect evidence showing it to have been warmer and wetter and, maybe, from direct evidence in meteorites that were catapulted off the planet and landed here on Earth millenniums later. The moons of Jupiter are far more dynamic than previously thought; Europa probably has an ocean of liquid water continually being heated by tidal forces; Ganymede has a magnetosphere; and Io is characterized by continuous volcanic activity. Venus has a surface hot enough to melt lead, while sulphuric acid and aerosols make its atmosphere equally inhospitable. Comets and asteroids bombard the planets. Not only have such collisions been observed first-hand (for instance, Shoemaker-Levy 9's impact with Jupiter): these bodies have also been approached close up to see their composition and bizarre topography. Now it is known that 65 million years ago the evolution of life on Earth suffered a catastrophic change as a result of the impact of an asteroid or comet.

8. In addition, the people on Earth have been privy to stunning observations of galaxies colliding or being born at the edge of the universe, new evidence for the existence of black holes and discoveries of planets orbiting other stars. The broad interest in such recent discoveries should not be surprising. The nature of life in the universe intrigues everyone, both rich and poor, in both industrialized and developing areas. Throughout human history, in all human cultures, people have wondered about their place in the cosmos, the nature of planets and stars and their relations to Earth, whether they are alone and the evolution of the universe, galaxies, stars, planets and of man himself. They have done this in their folklore, mythology, religion and culture, and now they can do it through science. Happily, that science is a complex and far-reaching task. The search for life in the universe (and indeed all aspects of planetary exploration and space science) require broad and multidisciplinary approaches: there is room for all. Through widespread communication, instant availability of data and information, and the interest of all—especially children—in exploration, space science and planetary exploration are becoming worldwide participatory activities, not just elitist ones.

9. Space science and exploration truly reflect the popular *raison d'être* for space programmes. Previous UNISPACE conferences placed emphasis on space science and exploration and this will be again a focal point in

UNISPACE III. While portions of the agenda properly focus on tangible space benefits for humanity that can flow from the application of space technologies and capabilities, it also gives attention to that part of space activity that engages the interest of a great number of people around the world.

II. PRACTICAL BENEFITS OF SPACE SCIENCE AND PLANETARY EXPLORATION

10. The discoveries cited above, and many others, have given birth to new understandings in many sciences: physics, astronomy, geology, biology and the environmental, ecological, engineering and computer sciences, for example. In addition to the intellectual benefits of new knowledge, however, many significant, mundane and specifically practical benefits have also had considerable effects on mankind:

(a) The "runaway" greenhouse effect on Venus, caused by an excess of carbon dioxide in its atmosphere, has led to an understanding of the dangers of carbon dioxide build-up on Earth and the resulting global climate change;

(b) The antiseptic surface of Mars, clean of any life or organic material because there is no ozone layer to protect it, provides a bleak description of what might happen if Earth's ozone layer were destroyed;

(c) Finding aerosols in the atmosphere of Venus and observing how they interact with the molecules there has led to knowledge about what happens when aerosols are introduced into Earth's atmosphere;

(d) Observing and analysing the dust storms on Mars have provided scientists with models of what happens to a planet's climate if massive amounts of dust are blown into the atmosphere, as would happen on Earth from a volcano or from the large impact of an extraterrestrial object;

(e) Asteroid and comet impacts on the terrestrial planets have profoundly influenced their evolution and it is now known that on Earth such impacts have wiped out species such as dinosaurs in the past and could do so again in the future.

All these observations have significance for all peoples of the Earth.

III. MOTIVATING EDUCATION AND SCIENTIFIC LITERACY

11. In towns and villages anywhere on Earth, youngsters show an interest in the stars and planets. Discussion of them in a classroom motivates learning, especially in modern sciences and mathematics. Astronomy has long been a pace-setter in motivation and in applications for education and the development of scientific literacy. Ever since Galileo wrote *The Starry Messenger*, astronomy has been a means of communicating science and mathematics to the public and a motivator for children to learn those subjects. In the twenty-first century world of information and technology, broad understanding of science, mathematics and technical subjects is crucial if people are to improve their quality of life. Through the World Wide Web, other Internet services, the public media, satellite television, educational and motivational programmes and telerobotics, the findings of space science and planetary exploration will be available to all. They can catalyse learning. To assume that modern space science and planetary exploration are not relevant to a poor or illiterate population only ensures that they will remain so.

12. Scientific illiteracy is one of the world's greatest problems and an increasingly divisive factor between haves and have-nots. Increase in the quality of life and economic growth now depend to a large extent on scientific and technical awareness and on the ability to incorporate new knowledge and devices into the economics of societies and the lives of individuals. While learning about Jupiter's atmosphere does not necessarily contribute to income-generation or solve economic problems, learning about the exploration of Jupiter is an integral part of a whole educational experience, motivating students and teachers to understand the global environment better. Dealing with

the brain drain is a major challenge in many countries: young people are turning away from creative enterprises of high achievement because of lack of opportunities. Some bright young people interested in science and technology may go to major industrialized countries to seek opportunities, but others are discouraged by the lack of opportunities and follow less productive paths because of higher financial incentives. In the past, weapons technology was an area of opportunity for creative engineering in the United States of America and countries of the former Union of Socialist Soviet Republics. The end of the cold war is now fortunately reducing the demand for new weapons, but the need for creative outlets for the human imagination remains and the opportunity for it to be exercised peacefully is now greater. Space work is not the only opportunity, but it is one of the best and certainly one of the most motivating.

13. The technology of exploration is crucial in this respect. Communications, remote sensing, miniaturization, propulsion, electronics, information processing and navigation are developments needed in all countries. Of course, these and other technologies and engineering skills will be developed in far more widespread applications than in space science alone, but the power of space science in the educational system to motivate the learning of such skills cannot be overestimated. The distinguishing feature of space science is the means by which it advances exploration. This captures public interest and provides a vision like little else in modern science and technology.

14. Large rockets are required to get to the planets, which is why only a few nations have conducted planetary missions. However, participation in the missions through scientific instruments, interdisciplinary investigations, education and public information programmes, engineering subsystems, high-technology manufacturing and innovation can all be done on a small scale as well as a large one. One or two scientists or a university group can make a substantive contribution, bringing credit to and interest throughout a whole country. Of perhaps greater potential is the redirection of military technology and expenditure to civilian space applications, employing the same technical disciplines, applied to a problem of even greater motivation: the exploration of the universe.

15. Basic scientific exploration has invariably been a catalyst for the development of a variety of new technologies. Space technology is no exception, driven as it is by the exacting requirements of space science and astronomical experiments requiring very accurate pointing mechanisms, better attitude-control systems and a variety of highly sensitive sensors. It is widely recognized that today's science is tomorrow's technology and that any nation that wants to advance technologically cannot afford to ignore investments in space science.

IV. CREATING A FOCUS FOR SPACE SCIENCE

16. The United Nations, and specifically its Committee on the Peaceful Uses of Outer Space and Office for Outer Space Affairs, could take the lead in involving both the scientific communities and the general public of developing countries in space science and planetary exploration. These bodies are the only institutions in which representatives of "space-faring" and developing countries meet on a regular basis and thus have a natural role in this area, once a decision to give the subject added emphasis is taken. In addition, these bodies already concern themselves with making sure that the tangible benefits of space research are made available to the developing world; extending this focus as proposed in the present paper is quite consistent with that concern. In fact, the United Nations has already taken important steps in that direction, most notably by convening a series of workshops on basic space science around the world.

17. However, there is more that might be done, as is outlined below. In addition to its emphasis on space applications, the United Nations could develop information and training programmes based on the results and activities of space science and planetary exploration for those in developing countries wishing to increase their scientific literacy. Workshops or symposia assisting scientists in responding to announcements of opportunities to participate in space missions and for educators and others interested in the broader issues of space science and planetary exploration could be convened under United Nations auspices. In addition, the United Nations could create a clearing-house for both print and electronic information at various technical levels using contributed funds to translate such material into various languages and to create a World Wide Web site for the

dissemination of information.

V. INTERNATIONAL AND REGIONAL BASIC SPACE SCIENCE WORKSHOPS

18. In 1991, the United Nations held its first basic space science workshop in India for Asia and the Pacific as a follow-up to the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE 82), held at Vienna from 9 to 21 August 1982. During that Conference the need to organize workshops and conferences in space science for developing countries was identified. The Office for Outer Space Affairs therefore developed the basic space science workshop programme for the period 1990-2000. The aim of the basic space science workshops was to help in bridging the gap in space science knowledge between industrialized and developing countries. Later in 1991 the first Space Conference of the Americas was held in San José, co-hosted by Costa Rica and Colombia, to stimulate collaboration in space science and space exploration among the Americas. The theme of the workshop included, in the first week, the solar system, planets, small bodies and planetary missions at San José and, in the second week, astrophysics, radio astronomy and cosmology in Bogotá. During the educational session of the Conference, interest was expressed by many countries of the region in workshops on space science. The Planetary Society (TPS), the United Nations and the European Space Agency (ESA) were represented at the Conference and jointly decided to organize basic space science workshops for the region.

19. Since then, workshops have been held almost yearly in different regions around the world, always concentrating on the needs of developing countries in space science. Workshops were held in 1991 in India for Asia and the Pacific, in 1992 in Costa Rica and Colombia for Latin America and the Caribbean, in 1993 in Nigeria for Africa, in 1994 in Egypt for western Asia, in 1996 in Sri Lanka for Asia and the Pacific, in 1996 in Germany for Europe and in 1997 in Honduras for Latin America and the Caribbean. The specific theme and focus of each workshop were defined by the host country taking into account the interests of the region, but the common theme was space science and scientific collaboration. During the workshops special attention was given to identifying areas of greater interest in space science as well as means to facilitate scientific collaboration. The workshops consisted of a combination of scientific presentations as well as working group sessions aimed at identifying the needs of the region with respect to mechanisms for cooperation in space science. The findings of each workshop were published in United Nations reports and in publications by the principal organizational sponsors.

20. In the report of the Sixth United Nations/European Space Agency Workshop on Basic Space Science, held at Bonn from 9 to 13 September 1996, it is stated (A/AC.105/657, para. 26):

> "The participants strongly recommended that the United Nations should exert its best efforts to ensure that the ... workshops on basic space science continue in the years to come ... such that the benefits ... are optimally oriented toward young scientists in the various geographical regions."

21. Besides the benefits to the region, there are additional benefits to the space science community from such interactions. TPS and ESA brought high-level scientists to the workshops who returned with new ideas and vitality in their work. (The participation of personnel of the Austrian Space Agency (ASA), the Centre national d'études spatiales (CNES) of France, the German Space Agency (DARA), the International Astronomical Union (IAU), the Institute of Space and Astronautical Sciences (ISAS) of Japan and the National Astronautical and Space Administration (NASA) of the United States of America, is also acknowledged.) The individuals involved have cited those benefits as the reason for their willingness to take time off at no pay to continue to provide workshop faculty and expert support.

22. Individuals in the countries and regions who participated in the workshops have testified to the benefits their attendance brings to their future careers and research. Such issues are important: this is how we build indigenous infrastructure and develop a global community of participants. The basic space science workshops for developing countries have been conducted over the past seven years; they have proved very successful both in promoting an

infrastructure and interest in developing countries for space science and in leading to specific space science projects for developing country participation. A task force could examine how to continue them and consider their efficacy and cost, as well as the possibility of additional space agency funding to continue them.

VI. THE ROLE OF NON-GOVERNMENTAL ORGANIZATIONS AS A CATALYST

23. While the main work of space development must come of course from national and international space agencies, non-governmental organizations can play an important catalytic role in partnership with governmental organizations in bringing together needs and capabilities from different sectors of society. Operating with less formality and constraints, and with more focused agendas, non-governmental organizations can serve as both advocates and team-builders for international cooperation, with both working scientists and the general public. Certainly, TPS has played such a role in its Mars programmes and in other planetary missions, but the real focus here is to suggest that non-governmental organizations should serve as catalysts in education and public information. They can help bring together the powerful and considerable materials produced in ESA, the Indian Space Research Organization (ISRO), NASA, the National Space Development Agency (NASDA) of Japan, the Russian Academy of Sciences, the Russian Space Agency (RSA), and many other space agencies, the educational resources of international organizations such as the Committee on Space Research (COSPAR), the International Astronautical Federation (IAF), IAU, the International Council of Scientific Unions (ICSU) and the United Nations system, the scientific professional organizations and the larger public community of students and interested adults, educators and organizations throughout the world who want to participate and want to receive the benefits of space science and exploration. Possible activities that could be undertaken by non-governmental organizations in partnership with space agencies and the United Nations are described in sections VII and VIII below.

VII. EDUCATIONAL MATERIALS AND CURRICULA

24. The United Nations is effective in distributing information, and providing communications for scientists and educators in developing countries who often do not have access to the products produced by the space agencies and aerospace educational organizations. More and more, ESA, NASA and others are turning to the Internet, and in particular the World Wide Web, for their outreach, as they are forced to reduce personnel, material, printing and mailing costs in their programmes. The Web is not really worldwide, however, and Internet access is extremely limited in developing countries. Supplementary programmes are therefore needed to make use of the existing material.

25. In addition to what individual organizations can do, a focused and coordinated programme is needed to leverage individual efforts into truly global ones. There are many outstanding publications and materials available in the educational community and from the space agencies. Help and financial resources are needed in translating and packaging them, for mailing and other distribution. This could be done at relatively low cost. Distribution in such a programme should be proportional to the population in the regions of the world and limited to developing countries in need. It is suggested that no organization contributing material be accepted unless it pay some of the costs of reproduction for global dissemination. Anything that can be done with the exciting materials from the space sciences will be a help in increasing education and awareness. In turn such an overall gain in scientific and technical literacy would contribute to economic and quality of life development in the world.

VIII. SPECIFIC PROJECTS AND TECHNICAL CONTRIBUTIONS

26. A number of specific follow-up projects have included technical involvement of developing countries in basic space science. Of particular interest to the United Nations are the projects being implemented in follow-up to the workshops on basic space science mentioned in section V above:

(a) The Mars drill study in Egypt, with the cooperation of the Russian Federation and TPS;

(b) The refurbishment of the Kottamia observatory in Egypt;

(c) Development of a telescope facility in Sri Lanka;

(d) A galactic emission map project, using a radio telescope, in Colombia;

(e) An astronomical observatory in Honduras;

(f) Publication and distribution of a space science and planetary exploration newsletter in Africa.

27. In addition there are now satellites being developed in countries not hitherto among the space-faring nations, Argentina, Brazil, Indonesia, Israel, Mexico, the Republic of Korea and Thailand, to mention a few. International programmes among Latin American, Arab and Asian companies are also developing satellites. China and India have long had an active space programme and space science capability. There are astronomy projects and programmes and instrument and science participation can be expected in many countries.

28. Some particular projects in space science that can be cited are:

(a) Argentina being the only country in the world to provide government support to the radio astronomical search for extraterrestrial intelligence (with operational support to the META II project installed there by TPS.

(b) Participation by China in the ESA Cluster mission;

(c) Experiments in X-ray and gamma-ray astronomy conducted by India on satellites of the stretched Rohini satellite series (SROSS) and the Indian remote sensing satellite (IRS) series, its participation in the gamma-ray telescope of the Russian Federation and its development of a multi-wavelength observatory to be launched on the polar satellite launch vehicle (PSLV) from India;

(d) Satellite Argentino Científico (SAC) satellite development by Argentina, including the building of an X-ray spectrometer;

(e) Satellite de México (SATEX) spacecraft development by Mexico and the Universidad Autónoma de México Satellite (UNAMSAT) now successfully operating in Earth orbit.

29. Such projects enrich the space sciences and enable new ideas to be brought into circulation. In some cases, with the building of satellites or spacecraft components, they permit costs by one country to be decreased because of participation by others. In the long run that goal should be more and more attainable.

IX. MICROGRAVITY RESEARCH AND THE INTERNATIONAL SPACE STATION

30. The international space station will provide physical and environmental conditions that are not available in the same kind or to the same extent on Earth. One of the most important factors will be weightlessness or, to be physically more correct, reduced gravity, which has come to be known as "microgravity".

31. Gravity is one of the fundamental forces in physics, but not of course the only one that affects physical and chemical processes. The classic procedure for investigating unknown phenomena is to create laboratory conditions in which the various factors influencing a process are separated so that their effect can be studied in isolation. While

it is not impossible to exclude the effect of gravity on Earth, it is difficult and only possible for a short duration. In space, it becomes possible to achieve a reduction of gravity over a very much longer period.

32. In the field of life sciences there are proposals for research projects on the international space station that focus on physiological and biological processes. In this area, the station will undoubtedly act as a major springboard for scientific progress, since it will make it possible to subject experiments to space conditions over a very long period, as well as to provide sufficient experimental opportunities for physiological research in the crew members themselves.

33. In physics, new aspects of materials processing in space and of fluid physics occupy the foreground. It is expected that basic research on the international space station will be able to provide practical help for applications on Earth. Almost free of the influence of gravity, many processes important for modern technology can be studied and understood better. A good example are processes involving phase transitions, which on Earth play an important role in all combustion processes and hence in the production of energy and high-quality materials. The fuller knowledge that can be gained in space because of reduced gravity can make a decisive contribution back on Earth in understanding and controlling the Earth-bound processes better.

34. Another example involves the growing of protein crystals. That does not mean initiating mass production of particular protein crystals on the international space station, but growing and investigating particular crystals in space can help widen the theoretical and practical knowledge and in turn make it possible to master or improve the corresponding crystal-growing processes on Earth.

35. There are, in physics, other proposals for using the station for experiments in fundamental physics, for example, for experiments on how dust, aerosols and plasma particles behave in conditions of weightlessness.

36. In the field of basic space science, one of the first concrete research projects that ESA, for example, will install on the international space station will be devoted to the improvement of atomic clocks. The atomic clock project is called the atomic clock ensemble in space (ACES).

37. The core of the ACES project, developed by CNES, is a laser-cooled caesium atomic clock called "Pharao", which makes use of the conditions of microgravity on board the international space station to reach unprecedented precision not achievable on Earth. In fact, a cold atomic clock will work more accurately under weightlessness on the space station than under gravity on Earth. This is related to the principle of "atomic fountain" used in the clock. Under the conditions of microgravity on the station, the cold atom cloud traverses the microwave cavity at a slower speed than on Earth. This makes it possible to increase the interaction time between the caesium atoms and the microwave field to 5 to 10 seconds, which in turn reduces the atomic resonance line width. The result would be an improvement of the frequency stability and accuracy of the atomic clock by a factor of 100 over conventional devices on Earth.

38. The operation of the laser-cooled caesium atomic clock Pharao on the international space station opens opportunities in various fields of fundamental research and application fields. The ultra-precise measurement of time will also make possible relativistic measurements and tests, applications in atmospheric physics and geodesy, navigation and advanced telecommunications.

X. APPRAISAL

39. There are four main reasons why humanity is interested in the study of basic space science:

(a) Because the knowledge of phenomena elsewhere in the universe can be of benefit in addressing some of the problems on Earth;

(b) Because basic space science has deep roots in virtually every human culture;

(c) Because it helps to understand man's place in the vast scale of the universe;

(d) Because it teaches man about his origins and evolution.

40. The study of basic space science and the benefits derived from it are critical to humanity's future well-being:

(a) Because basic space science is a fundamental element of education;

(b) Because it facilitates international cooperation;

(c) Because it leads to technological developments;

(d) Because it encourages young scientists and engineers;

(e) Because it develops a vision for the future.

Distr.
LIMITED

A/CONF.184/BP/7
27 May 1998

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COMMERCIAL ASPECTS OF SPACE EXPLORATION, INCLUDING SPIN-OFF BENEFITS

Background paper 7

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V.98-53889 (E)

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PREFACE

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Other objectives of UNISPACE III will be as follows:

(a) To provide developing countries with opportunities to define their needs for space applications for development purposes;

(b) To consider ways of expediting the use of space applications by Member States to promote sustainable development;

(c) To address the various issues related to education, training and technical assistance in space science and technology;

(d) To provide a valuable forum for a critical evaluation of space activities and to increase awareness among the general public regarding the benefits of space technology;

(e) To strengthen international cooperation in the development and use of space technology and applications.

As one of the preparatory activities for UNISPACE III, the United Nations Office for Outer Space Affairs of the Secretariat has prepared a number of background papers to provide Member States participating in the Conference, as well as in the regional preparatory meetings, with information on the latest status and trends in the use of space-related technologies. The papers have been prepared on the basis of input provided by international organizations, space agencies and experts from all over the world. A set of 12 complementary background papers have been published and should be read collectively.

Member States, international organizations and space industries planning to attend UNISPACE III should consider the contents of the present paper, particularly in deciding on the composition of their delegation and in formulating contributions to the work of the conference.

Sources and information provided by the World Meteorological Organization (WMO), the European Space Agency (ESA), the Centre national d'études spatiales (CNES) of France, the National Aeronautics and Space Administration (NASA) of the United States of America, the International Space University (ISU), France, and the President of the International Society for Photogrammetry and Remote Sensing (ISPRS) and review of the paper by experts from ESA, CNES, the Canadian Space Agency (CSA), the Indian Space Research Organization (ISRO), the Department of Space of the Government of India, the National Institute of Aeronautics and Space (LAPAN) of Indonesia, ISU, University College London and Novespace, France, are gratefully acknowledged. The following publications have also been used in the preparation of this paper: (a) "State of the space industry—1997 outlook", developed by SpaceVest (KPMG Peat Marwick, Space Publications, Center for Wireless Telecommunications); (b) the series of "Spin-off" publications produced by NASA; and (c) the European Community's working paper entitled "The European Union and space: fostering applications, markets and industrial competitiveness".

The assistance of M. J. Rycroft (ISU and Cambridge University, United Kingdom of Great Britain and Northern Ireland) as technical editor of background papers 1 to 10 (A/CONF.184/BP/1-10) is also gratefully acknowledged.

SUMMARY

Space activities incorporate some of the most important areas of high technology: computer software and hardware development, sophisticated electronics, telecommunications, satellite manufacturing, life sciences, advanced materials and launch technology. Space activities also involve some of the most significant issues of international trade and policy: global markets, gaining access to remote areas, government-subsidized competition and international standardization and regulation.

With an estimated US$ 77 billion in revenues and more than 800,000 people employed worldwide in 1996, the global space industry is one of the important economic engines of the world. The space industry also represents an immensely valuable bank of know-how that is used by thousands of companies worldwide to bring new products, processes and services to the world market at more competitive prices. Such indirect effects of space technology applications, which in the past were considered by-products of research and development, are increasingly looked upon as primary effects and a meaningful element of an industrial policy. Non-space industrial sectors are more demanding of new technology, new processes and new materials in order to remain competitive in their fields. The origin of much of the new spin-off technology can be found in space industry.

The present paper reviews the status of the space industry, the main segments of the commercial space market, market trends and statistics. Special emphasis is placed on issues associated with space technology transfer and spin-offs.

I. OVERVIEW

1. For more than 40 years, space has proved to be of crucial strategic, political, socio-economic and scientific importance. Both the major economic Powers and the developing nations have established and implemented programmes to enable all the parties involved, essentially the public authorities, industry and academic institutions, to demonstrate and exploit the potential of space technologies. The creation of international space organizations, national space agencies or authorities and research and applications institutions has stimulated the development of technological capabilities and industrial infrastructures, along with growing user/consumer markets all over the world.

2. As a result of that effort, the global space industry has become one of the largest industries in the world, with an estimated US$ 77 billion in revenues and more than 800,000 people employed worldwide in 1996 (this includes infrastructure, telecommunications, applications and support services). To appreciate the economic importance of the industry fully, it must be seen as a key element in a larger value-added chain. Usually, the bulk of that chain is made up of services, which together with the ground and user segments may represent more than 10 times the value of the spacecraft and launchers. Therefore, the narrow view of the space industry as limited to the space segment manufacturers should be avoided.

3. In addition to economic interests, practically every country could have strategic interests in the development of or access to space applications. These have an impact on such important components of policy as the environment, agriculture, sustainable development, communications networks, natural disaster prediction, education and health care, to name but a few. In that context, when space technology is placed in the proper political framework, it may play a key role in policy- and decision-making processes at the national, regional and international levels.

4. The geographical distribution of space activities and, consequently, of space-related industrial and research potential has an uneven character, with a higher concentration in the major economic Powers, followed by a number of developing countries. The same may be true for the benefits derived from space technology applications. However, as space systems are neutral from a geographical point of view, they could favour relatively more the less advanced countries and regions and thus have a higher impact on the political, economic and social processes in such areas.

5. Since the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE 82) held at Vienna from 9 to 21 August 1982, the space industry, including the ground segment and related services, has had to cope with a number of global political, economic and technological changes that have had a strong impact on the industry's operating environment. Those changes include but are not limited to the following:

(a) The end of the era of geo-political antagonism, which had fuelled the growth of the space industry for decades;

(b) The economic slowdown experienced by many countries and, as a result, tied budgetary policies directly affecting space research and development programmes;

(c) Increased globalization and the opening of the international marketplace, as well as the emergence of new competitors;

(d) The global trend towards the liberalization and deregulation of telecommunications services and privatization of many traditional government space activities;

(e) Recent technological developments and the convergence of telecommunications and information technologies;

(f) The acceptance of space commercialization by the capital markets.

6. Some of the above factors may be of a temporary nature, whereas others will require permanent changes in the way the industry operates and in the role of Governments in the field. Industry is conscious of the fact that its present structure will have to be adapted in response to those changes, but, in many cases, still lacks a clear indication from the appropriate government authorities as to what the new environment will be.

7. Though the development of the space industry worldwide still depends to a large extent on government funding for research and development and procurement of both civilian and military systems, the above-mentioned transformations are changing that situation. It is therefore quite likely that, over the next five years, the commercial market may overtake Governments as the largest customer of the space industry.

8. The most striking departure from past practices is the totally private financing of radically new telecommunications systems, such as mobile systems based on low- and middle-Earth orbit (LEO and MEO) satellite constellations for a cost of US$ 2.5 billion to US$ 5 billion over three to five years. In 1996 alone, almost US$ 3 billion was raised on financial markets for the financing of space projects. The demand for satellite services has, in turn, driven the launch service market.

9. Fuelled by current and planned commercial applications, many with growth rates greater than 20 per cent annually, total industry revenues are expected to surpass US$ 100 billion before the year 2000, with continued growth projected through the early years of the next century.

II. SPACE MARKET SEGMENTS

A. Satellite manufacturing

10. Spawned by continued government procurements coupled with the tremendous demand for commercial telecommunications, remote-sensing and mobile LEO systems, space manufacturing has experienced unprecedented development in recent years. Historically, growth projections for the manufacture of commercial satellites and launch vehicles have been revised upward on an annual basis as demand has exceeded expectations. That trend is expected to continue as several mobile communications systems and new multimedia services begin operations over the next few years. A certain downturn is forecast in the number of satellites ordered in the period 2001-2005, relating to the time between the period when the satellites currently on order are placed into orbit and when their replacements need to be built and launched (see table 1).

Table 1. Satellite manufacturing activity
(Millions of United States dollars)

	1995	*1996*	*1997*[a]	*1998*[a]	*1999*[a]	2000[a]
Commercial	2 739	2 989	3 884	5 044	6 552	8 510
Government	5 883	5 959	5 946	6 100	6 093	6 079

Source: *State of the Space Industry: 1997 Outlook.*
[a]Forecast.

11. The strong and continuous demand for new satellite manufacturing is stimulated by a number of market trends. These may be summarized as follows:

(a) *Demand for greater telecommunications capacity*. More bandwidth is required to satisfy the steadily growing demand for the transfer of data, voice and images. Expansion of the overall capacity will take place through the deployment of new infrastructure, as well as development of new technologies for signal compression. Until new compression techniques are proven and tested, the capacity will expand predominantly through increases in satellite infrastructure, as it provides a quick and relatively inexpensive means of expansion.

(b) *LEO/MEO market*. Numerous planned mobile satellite services based on LEO and MEO satellite constellations require hundreds, if not thousands, of satellites to be manufactured, not to mention spares. As the demand for mobile satellite services is rising, this will keep the space industry with a steady backlog of orders for such satellites;

(c) *Reduced manufacturing cost*. The development of satellite constellations, as well as the need for more geostationary satellites, is expanding technology and providing manufacturers with an opportunity to improve efficiency. As the cost of manufacturing and launching satellites decreases, users of the next generation of satellites will create a number of new applications made possible by lower costs;

(d) *Small satellite market*. Manufacturing activity for small satellites is expected to more than triple by the year 2002, with scientific missions, the qualifying and testing of new hardware in space and emerging applications driving that expansion. Previously limited only to scientific missions, new technologies are beginning to allow the use of such satellites for commercial applications, including telecommunications and Earth observations. A number of small and medium-sized manufacturers worldwide are promoting the use of small satellites for various niche markets. Several universities in different countries, including developing ones, have been designing and manufacturing small satellites both as a teaching tool for students and platforms from which to operate small scientific experiments;

(e) *Future applications*. New applications of space technologies and services are currently being developed. Services such as remote monitoring of the status of oil pipelines, automated data collection and satellite-routed access to the Internet, to name but a few, will further the need for additional satellites to be manufactured and deployed.

B. Launching services

12. Between 1987 and 1996 the commercial market amounted to 36 satellites launched on average each year. With a projected 1,697 satellites to be launched during the period 1998-2007, the commercial launch-vehicle industry is forecast to expand at more than 10 per cent annually. The nature of the demand is also changing. Geostationary orbit (GEO) satellites are growing in mass, the time between their purchase and launch is being reduced greatly and the launch of constellations has become a thriving commercial trend.

13. The total market value for launching services over the decade 1997-2006 is estimated at US$ 33.4 billion, of which US$ 21 billion will be used for launching GEO satellites (based on the conservative estimate of 262 GEO satellites given in section D below). Of the US$ 21 billion for GEO, 55 per cent are already covered by firm contracts signed by October 1996 and another 6 per cent are considered "captive", leaving 39 per cent of the market still open for international competition. About two thirds of the total market value will be generated by commercial operators, the remainder coming from government agencies (see table 2).

Table 2. Launch-vehicle revenues
(Millions of United States dollars)

Expendable launch vehicle	*1995*	*1996*	*1997[a]*	*1998[a]*	*1999[a]*	*2000[a]*
Commercial	1 325	1 811	2 214	2 400	2 594	2 700
Government	3 101	3 143	3 134	3 220	3 215	3 205
Total	4 426	4 954	5 348	5 620	5 809	5 905

Source: *State of the Space Industry: 1997 Outlook.*
[a]Forecast.

14. Current launch manifests for commercial payloads are booked through 1999, with a record number of flights scheduled in order to meet demand. In addition to placing payloads in geostationary orbit, several of the proposed LEO ventures began launch campaigns in 1997.

15. Expendable launch vehicles (ELVs) currently make up the greatest part of the commercial market for placing payloads into orbit. Based on proven technology, current ELVs have historically achieved a better than 80 per cent success rate for placing payloads into orbit, at a cost of between US$ 16,000 and US$ 20,000 per kilogram. New ELVs or upgrades with potentially scalable lifting capabilities are currently under development a number of countries.

16. A number of small launchers (such as Cosmos, Pegasus, Taurus and polar satellite launch vehicles (PSVLs) are being used for placing small satellites into orbit by various countries. With small spacecraft costing substantially less than larger ones, the market for placing such payloads into orbit is expected to grow dramatically. Led by a market fuelled by the "space-faring" nations, researchers and companies with limited budgets, over 10 different vehicles are under development, including offerings from Brazil, India and Israel.

17. Reusable launch vehicles (RLVs), that is, vehicles that can leave the Earth's surface, place a payload in orbit, return to Earth and be refuelled for another launch, are seen by industry as a way to reduce the cost to orbit by a factor of up to a 100. The Space Shuttle represents the only operational RLV to date, but its use for placing commercial payloads into orbit is precluded by United States government policy. Several new RLV projects under development (such as Eclipse, K1, Hope X and X-33) are planned for commercial use. The development of those projects still faces many technical challenges, such as keeping the weight of the vehicle down and the need for new materials, structures and control systems. Once operational, however, those RLVs would initiate a rapid expansion of the space industry, enabling new applications as a result of the substantial reduction in launch costs.

18. Another important component of launching services is launch facilities or spaceports. Though a relatively modest growth in revenue is expected within the sector, its activity is at a historical high. Several new facilities are scheduled to begin operations in the next few years, while additional resources are being channelled to modify existing spaceports in order to handle multiple types of launch vehicles. They are expected to reduce the time to launch and support requirements and to save millions of dollars in annual operational costs. An ocean-based launch platform, commercially developed with the participation of companies from a number of countries, is expected to begin operation in 1999.

19. The international marketplace for launch services is expected to be highly competitive over the next few years owing to the international marketing of several launch vehicles with overlapping payload weight

capabilities. While the Delta, Atlas and Ariane vehicles have in the past launched most of the commercial payloads, launchers from the Russian Federation, Ukraine and China take a relatively small share of the overall market, owing to agreements signed with the United States of America limiting the number of commercial launches those countries are permitted to conduct (see table 3).

Table 3. 1992-1997 market share based on number of commercial payloads
(Percentage)

United States of America	33.0
Arianespace	48.5
Commonwealth of Independent States/China	18.5

Source: United States Department of Transportation.

20. With current demand outstripping supply, an oversupply of launch vehicles is forecast by some industry analysts when some other countries with launching capabilities enter the international marketplace of launch services and when the number of projected payloads levels out between 2002 and 2006. However, estimates of the number of payloads to be placed into orbit have routinely been underestimated and new emerging applications may spur on the further demand for launch services.

C. Ground segment (ground station design, manufacturing and operation)

21. The ground segment for supporting space systems and services is one of the largest markets within the space industry. Demand for ground facilities, mobile receivers, handsets, very small aperture terminals (VSAT) and direct broadcast receivers has been growing substantially over the past few years, with higher growth forecast for the near future (see table 4). In addition to hardware that receives data broadcast or distributed via satellites, the ground segment of the space industry also includes other activities and services, such as the operation and monitoring of satellites and testing facilities. Predominantly, the largest source of revenue within the sector is from the operation and manufacture of receivers and transmitters, including hub stations, VSAT terminals, direct-to-home (DTH) dishes and mobile handsets.

Table 4. Ground segment revenues
(Millions of United States dollars)

	1995	*1996*	*1997*[a]	*1998*[a]	*1999*[a]	2000[a]
Ground equipment	10 740	11 330	12 830	14 450	15 670	17 240
Space Shuttle operations	3 176	3 144	3 151	2 998	3 019	2 979
Other operations	7 208	7 275	7 218	7 448	7 401	7 380

Source: State of the Space Industry: 1997 outlook.
[a]Forecast.

22. For the past few years, the two products driving this segment have been VSAT terminals and direct broadcast antennas. VSAT networks link factories with main offices, retail stores with central purchasing offices and remote consumer service equipment with central processing facilities, and are increasingly used by financial institutions to link remote branches with central computers. Primary usage has been by large corporations for voice, data and video communications, but small companies and consumers are now joining the purchasers of small Earth stations. More sophisticated satellites, less expensive ground equipment and better software have led to VSAT transmission services becoming competitive with the services provided by dial-up lines. VSAT sales worldwide are expected to increase by 62 per cent between 1995 and 2001. In Asia and the Pacific, the growth is expected nearly to triple. North America, with an estimated US$ 88 million in sales, is expected to grow slightly less than 40 per cent. The European market is expected to double and Latin American demand to increase nearly two and half times over the six-year period. Such growth may be accelerated by the planned introduction of interactive, two-way mesh VSAT networks.

23. Satellite antennas that receive digital direct broadcast signals have become the fastest-growing consumer electronic products, with most of that growth occurring in the United States and Europe. Worldwide, a dramatic increase in manufacturing and sales of such equipment is expected to take place between 1997 and 2000, as direct broadcast satellites are due to be placed in orbit over the markets of Latin America, Asia and the Pacific and the Middle East. In the four years from 1997 to 2000 sales are expected to quadruple.

24. Beginning in 1998, the sale of mobile terminals and handsets for transmitting and receiving signals from LEO satellite constellations is expected to generate significant new revenues. Personal communications system handsets and mobile terminals relying on various LEO/MEO satellite systems are expected to generate sales of hundreds of millions of dollars over a five-year period.

25. Supporting ground stations, which control the satellites and the flow of data from them, constitute one of the most important segments of the space industry. Although the number of satellites and ground stations is increasing, growth in the ground operations market is flat because of better computer hardware and commercial off-the-shelf software allowing satellite operations to be handled in-house and in a more efficient way.

D. Telecommunications*

26. The telecommunications satellite market is certainly the most mature space market. According to some studies, the world market for commercial geostationary communications satellites between 1996 and 2006 is estimated at some 262 to 313 satellites, with a total value of between US$ 23.8 billion and US$ 28.7 billion. To this should be added the LEO and MEO constellations for mobile telephony and multimedia applications. Combined with the deregulation of the world's telecommunications, the existing and planned satellite systems create an unprecedented potential for the satellite telecommunications services market, with substantial room for growth (see table 5).

27. Given its inherent cost and capability advantages for supporting many global and mobile services, satellite telecommunications have evolved into a core part of the US$ 550 billion global telecommunications marketplace. The transmission of international telephony services, interconnection with national telephone networks and distribution of video signals for cable and television programmers have provided a core base of revenue for the sector. The worldwide growth of those activities, combined with new services requiring expanded bandwidths and the capability to operate in nearly every country almost immediately, will quickly lead to a tripling of direct satellite revenues for those services to an estimated US$ 29 billion by the year 2000.

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*A detailed description of satellite telecommunications services and applications is given in background paper 5, "Space communications and applications" (A/CONF.184/BP/5).

Table 5. Revenues in some sectors of the telecommunications market
(Millions of United States dollars)

	1995	*1996*	*1997[a]*	*1998[a]*	*1999[a]*	*2000[a]*
Fixed satellite services—transponder leasing	4 300	5 000	5 775	6 584	7 505	9 000
Mobile satellite services	780	850	1 450	2 400	4 500	8 000
Direct-to-home services	1 800	2 856	4 600	6 800	9 400	12 000

Source: *State of the Space Industry: 1997 Outlook.*
[a]Forecast.

28. Another service driving the telecommunications market is direct broadcast satellites. Worldwide, DTH satellite television services are expected to meet the needs of more than 800 million television households and more than 2 billion people now without access to television.

29. With rising worldwide demand for mobile satellite services, especially in developing countries, which often lack an adequate terrestrial telephone line infrastructure, planned LEO and MEO systems will supplement GEO satellite communications services. The development and commercial operation of mobile satellite services is expected to reshape the market dramatically by lowering access costs and expanding overall capacity.

30. Mobile satellite service systems will offer the following three types of services: (a) worldwide personal communications services to users via single- or dual-mode cellular/satellite phones; (b) mobile data terminals used to transmit "store-and-forward" messages; and (c) fixed applications in the developing countries and emerging markets such as "village phones". Those services would also provide numerous opportunities for commercial applications such as fleet and cargo tracking and monitoring, low-cost messaging to rescue workers, transmitting data from remotely monitored automated devices (unattended pipeline control stations, automated platforms for collecting environmental and weather data in rural areas and so on) and stolen property recovery.

31. With an unserved telecommunications market estimated at 5 billion people, the satellite telecommunications market has substantial room for growth. The deployment of new GEO and constellations of LEO satellite systems will enable low-cost telephony access to even the most remote areas of the world. Such access will spur numerous commercial services in areas such as telephony, high-speed data transfer, connection to the Internet, tele-medicine, tele-education, tele-banking, emergency communications, distribution of video signals for cable and television programmers and other multimedia applications, thus making the global information highway a reality.

32. The use of satellite communications for sustainable development, training and mass education purposes is a socially important component of the telecommunications sector. Extensive experience gained by several developing countries, including Brazil, China and India, through experiments in the area has demonstrated the potential of satellite communications systems for developing countries in this respect.

E. Remote sensing and geographic information systems*

33. Next to the telecommunications market, remote sensing and geographic information systems (GIS) may be among the most significant commercial applications in the space industry (see table 6). Remote-sensing data are widely used in agriculture, civil planning, environmental management, forestry, natural resource management and many other applications. With the launch of 20 new remote-sensing satellites expected by the year 2002, the capacity for data collection will increase dramatically. The new systems will include sensor technology that will provide users with the option of spatial resolutions down to one metre. This will be combined with other factors driving the industry, including the increase in cost-effective computing power and data-compression capability, as well as the related increase in sophistication of applications adapted to specific user needs and more user-friendly software.

Table 6. Remote-sensing and geographic information systems revenues
(Millions of United States dollars)

	1995	*1996*	*1997[a]*	*1998[a]*	*1999[a]*	*2000[a]*
Remote sensing	535	611	698	838	1 048	1 234
Geographic information systems	1 200	1 428	1 699	2 022	2 406	2 864

Source: *State of the Space Industry: 1997 Outlook.*
[a]Forecast.

34. The impact of remote-sensing activities on various segments of the global space market may be estimated as follows:

(a) From US$ 580 million to US$ 620 million a year for satellite manufacturing, including both meteorological and remote-sensing spacecraft and payloads;

(b) From US$ 230 million to US$ 250 million a year for satellite launches, funded by the space agencies;

(c) US$ 60 million a year for sales of raw data used mostly for commercial purposes and priced in a number of ways, ranging from the marginal cost of reproduction to a price reflecting a steady transfer of the operating cost to users and, in the longer term, the cost of satellite system renewal;

(d) From US$ 280 million to US$ 300 million a year for manufacturing ground equipment for receiving, storing and processing satellite data;

(e) From US$ 830 million to US$ 850 million a year for remote-sensing data distribution, processing and interpretation services and the sale of value-added products and services, essentially by private companies, primarily to public, semi-public and cooperative organizations concerned with pollution control, agriculture, utility infrastructure, urban planning, zoning and water management.

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*A detailed description of remote sensing and geographic information systems applications is given in background paper 3, "Management of Earth resources" (A/CONF.184/BP/3).

35. Within the next 10 years this market is expected to grow by a factor of three to five, depending on the development of some promising market segments (such as real estate, utilities, legal services, insurance, precision farming and telecommunications, which should be conceived increasingly as market niches for specialized value-added product/service suppliers. The expansion of the market will also depend on the restructuring of the present data/product distribution system to one of solution-oriented systems that can serve a larger number of public and private enterprises dealing with real estate development, disaster-related losses, crop insurance, small projects, environmental assessment, wasteland reclamation, infrastructure and utilities that can afford to pay much higher fees for the value-added services.

36. GIS are a tool for assessing, integrating and distributing large spatially referenced sets of data. With their capability of combining data derived from multiple sources—satellite imagery, digitized maps, census bureau data, soil composition, vegetation, types of water supply and so on—in order to present an overall picture of the situation in a given area, GIS have become extremely valuable in numerous applications, ranging from business and market analyses to disaster management planning, and from environmental monitoring to urban development.

37. Originally, the use of GIS was limited to Governments, universities and large companies that could afford the infrastructure, which included expensive and sophisticated software and hardware, and to researchers and trained technicians. As the technology has advanced, off-the-shelf software for personal computers has opened up access to the GIS market to a variety of new users, mostly small and medium-sized companies all over the world. Fuelled by the growing demand for GIS services and software, this market could reach a level of US$ 5 billion in sales by the year 2000.

F. Navigation services*

38. Since 1993, when the global positioning system (GPS) was declared operational, the market for GPS equipment alone has increased from about US$ 0.5 billion to US$ 2 billion in 1996, and is expected to reach US$ 6 billion to US$ 8 billion in 2000. The most performance- and integrity-demanding applications (military, aviation and marine) correspond to the smallest market shares (2-5 per cent of the total market each), while the market share of civil ground applications, which already constitutes almost 90 per cent of the total market, will keep growing. The wide range of new commercial applications and services includes automotive navigation systems, emergency assistance, geodesy, GIS and precision engineering, among others. This market development has become possible as a result of the dramatic increase in GPS performance through the use of local or regional systems transmitting corrections and the steep drop in price of GPS equipment. GPS is thus becoming an enabling technology, fuelling the market by offering accurate, real-time positioning data to be integrated with other types of information.

39. The future use of GPS relies more and more on the consumer market. In fact, GPS services are expected to complete the transition from a stand-alone device to a standard feature integrated into a variety of multi-function products, such as wireless personal communications devices, leading to the development of true mass consumer markets, with the average selling price per unit being about US$ 100.

G. Space manufacturing and processing

40. Space manufacturing is the use of the near-zero gravity and vacuum environment of space for the production, processing and manufacture of materials for commercial purposes. This is a very broad definition, which includes industrial and research activities such as the zero-gravity production of metal alloys, plastics

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*A detailed description of satellite navigation services and applications is given in background paper 4, "Satellite navigation and location systems" (A/CONF.184/BP/4).

or glasses, the processing and analysis of organic matter and the study of the physiology and behaviour of humans, animals, and plants in the unique environment of space. While space provides a whole new realm of opportunity and a vast potential market for industry and business, it is still perceived by many as a final frontier rather than an economic market ripe for expansion. This is reinforced by the tremendous costs of today's space infrastructure, elements such as cost per kilogram launched, the cost of electricity generated in space, launch expenses and safety requirements.

41. The unique conditions of near-zero gravity in an orbiting satellite or spacecraft would allow industries to manufacture new materials simply because the absence of gravity allows for the creation of perfectly even and consistent mixtures of materials with vastly different mass and densities. These alloys would have physical properties that nobody on Earth could duplicate and could lead to the production of much faster computers, smaller and much more powerful batteries that could power future electric cars and many other new products. In order to facilitate the commercialization of the tremendous potential market of space, the cost of the basic space infrastructure must be reduced dramatically.

42. The international space station, with operations beginning early in the next century, will expand the segment's capabilities to perform both automated and manually operated experiments. However, with limited space and manpower and a backlog of scientific experiments, the station is expected to have less of an effect on commercial activities than unmanned reusable vehicles that can also serve as experiment carriers.

43. Governments should do more to promote, attract and aid the presence of private sector in space.

H. Other and future market segments

44. Many ideas and strategies have been proposed and in some cases implemented with a view to taking advantage of the bountiful prospects of the space market. These include space advertising and space burial services that are already commercially operational. Tourism in space may also prove to be a viable market for new space industries. If the costs of the space infrastructure are drastically reduced and safety levels increased, tourism in space could be a tremendous market.

45. Another potentially profitable space activity is the disposal of nuclear waste and other hazardous materials. The disposal of hazardous waste material has long been a problem for Governments and industries and continues to be so today. With the development of new technology and reduced costs, the ability to transport hazardous materials from remote locations on Earth into space and the propulsion of that material into far-out orbit could become a realistic and desirable option. Space can also provide an optimum location for orbiting platforms that can be used to transmit electrical energy to Earth and microwave energy transmission technology. This would be a new and environmentally safe method of generation and transmission of electrical power.

46. However, a fundamental aspect of all such innovative plans is the reduction—and minimization—of costs, thus making efficiency, economy and cost-efficiency primary concerns.

III. INDIRECT MARKETS

A. Support services

47. The support services segment is composed of a variety of space market services, such as engineering, technical support, business consulting, financial and legal services, space insurance and publishing (see table 7).

Table 7. Support service revenue
(Millions of United States dollars)

	1995	*1996*	*1997[a]*	*1998[a]*	*1999[a]*	*2000[a]*
Professional services[b]	1 321	1 227	1 228	1 188	1 152	1 115
Financial services	-	1 250	750	1 100	950	875
Space insurance	849	796	1 030	950	1 075	1 150
Publishing	12	13	14	14	15	16

Source: *State of the Space Industry: 1997 Outlook*.

[a]Forecast.

[b]The decline is due for the most part to those professional services which relate to overhead/general management support to Governments.

1. Professional services

48. The sophistication and complexity of new products and services offered by the space industry have led to a demand for specialized engineering and technical services that provide integrated system solutions and the incorporation of diverse technologies. New companies are entering various market niches of the space industry to meet the demand for experienced professional consulting and business service providers. In addition, a number of companies specialize in providing support to government agencies in a variety of capacities.

49. Fees associated with contract preparation, business activities and regulatory licensing of satellites and launch vehicles are expected to increase in proportion to the number of new commercial ventures. The growth of those services is forecast at about 10 per cent per year.

2. Space insurance

50. The space insurance market, with underwriting organizations in different countries, provides coverage for the loss of vehicles and payloads, damage to launch facilities and third-party liability. Vehicle and payload insurance covers the value of the launch vehicle and spacecraft from launch through initial operations and may also include coverage beyond that for commercial operations in orbit.

51. During 1996, insurance rates for space launches ranged from 15 to 18 per cent of the insured value. Gross premium revenues rose in 1996 to almost US$ 800 million. Payments for failures in 1996 totalled US$ 508 million, leading to the segment having a gross profit of US$ 288 million for the year. With an increased rate of launching expected for 1997-2000, insurance premiums are anticipated to reach over US$ 1 billion per year.

3. Financial services

52. The space industry is becoming an increasingly important sector of the financial service industry. Mergers, acquisitions and the raising of capital for new ventures are feeding the number of deals within the industry. According to market analysts, revenues jumped dramatically during 1996 as the number of initial public offerings, dealings with national regulatory bodies and the volume of mergers increased. Those revenues are expected to fluctuate from year to year, but remain at a level much higher than at the beginning of the 1990s.

4. Publishing

53. Business development activities depend on information. A large number of publications focusing on news, opportunities, legal and regulatory developments and technology transfer within the space industry exist to meet this need. In addition, specialized newsletters are published to inform the industry and market about technical and market niches.

B. Space technology transfer and spin-offs

54. The global political, economic and technological changes referred to in the introduction to the present paper have altered the space industry's operating environment. In that context, space technology is no longer a means to achieve political supremacy, but rather an economic asset and an immensely valuable source of know-how, which is used, through an extensive transfer process, by thousands of companies worldwide to bring new products, processes and services to the world market at more competitive prices.

55. The indirect effects of space technology applications, which were in the past considered by-products of research and development, are increasingly being looked upon as primary effects that can constitute a meaningful element of an industrial policy, with a strong impact on new market developments, economic growth and job creation or saving. Industrial sectors, which used to be almost independent as regards technology development, are more and more demanding in terms of new technologies, new processes and new materials, the origin of which can be found in the space industry. Further, the manpower devoted to "high-tech" developments in a company is a valuable asset, benefiting not only space activities. Accordingly, such indirect effects can also be considered primary objectives of an industrial corporate strategy.

56. Programmes of technology transfer and spin-off (i.e. products and processes that have emerged as secondary applications of space technology) developed by national and international space agencies now demonstrate a market-oriented approach, based on demand and clearly identified market segments. Thus, space technology no longer appears to be a luxury product and process, but more a reservoir of potential solutions for industry. Of course, that process requires a high level of interaction between the developer and the recipient of the technology, as well as a well-defined government policy and established organizational infrastructures.

57. Thousands of spin-off products have resulted from the application of space-derived technology in such fields as human resource development, environmental monitoring, natural resource management, public health, medicine and public safety, telecommunications, computers and information technology, industrial productivity and manufacturing technology and transportation (see table 8). Technology transfer and spin-off products and processes collectively make an enormous contribution to national economies, to the creation of new jobs and to industrial productivity. They also represent a substantial dividend on national investments in aerospace research.

58. The vast range of industries and products derived from spin-offs makes it impossible to calculate exact figures relating to their economic impact. The relatively long time to complete a technology transfer, which typically ranges from two to seven years, also raises difficulties in determining the overall annual revenue effect of spin-off technologies. In that respect, the development of a systematic quantitative and qualitative approach that measures the effectiveness of a spin-off programme in terms of both results and efficiency is extremely important in facilitating the process of transfer. Such measurements or metrics can then be used to improve the mechanisms and objectives of the programme. Current budgetary reductions experienced by many countries have become an additional reason for applying metrics that can be used to justify and promote both space research and development programmes and technology transfer programmes.

Table 8. Some examples of space technology spin-offs

Environment	*Health care*	*Industrial productivity*
Hazardous gas detectors	Patient-monitoring systems	Cable testers
Pollution-control devices	Portable X-ray equipment	Laser technologies
Wind generators	Physical therapy equipment	Wood-bond testing
Sewage-treatment systems	Invisible dental braces	Inspection tools
Image-processing software	New pharmaceuticals	Industrial robotics
Oil spill clean-up	Scratch-resistant lenses	Industrial control systems
Public safety	***Transportation***	***Computer technology***
Fire-fighting systems	Aircraft de-icing systems	Expert system software
Cathode-ray tube filter lenses	Car airbags	Software management systems
Radiation blocking	Car anti-lock braking systems	Data-acquisition systems
Noise-reduction technology	Electromagnetic compatibility test facilities	Error-free software
Traffic-monitoring systems		Image-compression devices
Advanced materials	***Construction***	***Consumer and home products***
Composite materials	Energy-efficient coatings	Redundancy flashlight systems
Dry lubricants	Accurate surveying	Art preservation
Teflon and non-stick coatings	Computer-aided design/manufacturing enhancements	Velcro fasteners
High-temperature coatings	Lightweight structures	Cordless tools
Metal coatings	Analysis software	Tang orange drink
Plasma-heating devices	Piping connectors	Water filters

1. Technology transfer strategies

59. The approaches used in technology transfer programmes by government agencies and industrial sectors across the world can be divided into three broad categories: technology-push, market-pull and interactive strategies. These are identified as the main strategies of innovation by which spin-offs occur.

(a) Technology-push strategy

60. This strategy was introduced in the 1960s and 1970s, when the priority had been given to the space industry to identify the know-how, expertise and products that could be used as transferable assets for non-space applications. In other words, the innovation process was "pushed" to the market by research and development in the belief that increased economic development could be achieved by increased funding for science only. That strategy, in which a given product or technology had to search for a particular application, often led to difficulties. In some cases, the product did not correspond to a market need, while in other cases, it corresponded to a real need, but the adaptation of the space technology became too costly. The level of risk inherent in many of the space technologies often discouraged the potential recipient company from investing in the adaptation.

(b) Market-pull strategy

61. Consequently, the space industry has developed a "market-pull" strategy, which starts from the potential customer's demand and systematically researches the market needs. Then the objective is to find the adequate technology, or set of technologies, that could offer a solution to the industrial, economic, societal or other problems. Such a market-oriented approach has the advantage of being based on demand and on clearly identified market segments. Of course, the process requires a higher level of interaction between the developer and the recipient of the technology. This approach corresponds to a "market-meet" strategy, in which the space companies acquire an in-depth understanding of the market needs and problems through face-to-face interaction with experts from both sides.

(c) Interactive strategy

62. The interactive strategy, also called the "chain-link" model of innovation, stresses the importance of the links between science, technology and the marketplace. The interactive strategy constitutes a linking of science and the market with a number of feedback loops. This approach attempts to satisfy the needs of technology transfer by approaching the problem from both ends, that is, by promoting both "push" and "pull". A distinguishing characteristic of the strategy is that at each step there is access and interaction with the knowledge base, as well as a greater responsibility of all parties for their part of the project, combined with greater communication between all those concerned.

2. Technology transfer mechanisms

63. The successful transfer of technology and spin-offs require appropriate methods and an infrastructure in place, as well as clearly defined government policy on the matter and support from it. Major mechanisms used for technology transfer and spin-offs are summarized below. It should be noted that not one but a number of mechanisms should be activated in order to establish an efficient technology transfer infrastructure.

(a) Organizational structure

64. Organizational structures in agencies and industry can either promote or discourage technology transfer. An example of a successful organizational mechanism in place to aid technology transfer and spin-offs in the space sector is the technology transfer and/or commercialization office established within a government space agency. Agencies that have a dedicated structure in place can demonstrate visible success in conducting and successfully completing technology transfer. Umbrella organizations devoted to promoting technology transfer between sectors can also be created. The role of the transfer offices, umbrella organizations and the technology brokers involved can be an extremely complex one, depending on the structure of the organization, its role and its constraints.

(b) Contractual mechanisms

65. Contractual mechanisms to aid technology transfer are a relatively recent development in the space sector and are based on an appropriate government or international space policy. Such mechanisms encourage private companies to enter into cooperative agreements with space agencies in order to develop commercially technologies already developed by agencies or to work with agencies' scientists to produce new technologies or products and to use the agencies' research facilities. Contractual mechanisms can promote cost-sharing, cross-fertilize ideas and reduce the duplication of effort. In a joint work programme, the parallel development of a technology can also lead to joint ownership and to shared profits. Such an approach is also very beneficial for small and medium-sized companies lacking their own research and development facilities or personnel.

(c) Marketing and market research

66. Marketing is an integral part of the commercial use of space technologies and is essential to technology transfer. The market demand for technology has led to the establishment of numerous technology brokerage companies. Brokers act as go-betweens in a transfer of technology, essentially matching donor to receiver and aiding both parties where possible. The establishment of spin-off companies as a result of technology transfer is very often a direct outcome of activities carried out by such brokerage companies.

67. Other marketing mechanisms focus on a widespread promotion of technology. These include such events as technology transfer exhibitions or fairs, awareness campaigns and conferences organized by space agencies, their umbrella organizations or brokerage companies. Also in this category are more passive mechanisms, such as technology catalogues and databases of marketable technologies, as well as various magazines and newsletters focusing on technology transfer and spin-off benefits. The latter, however, rely on donors and receivers having an active interest and motivation in finding technological partners.

(d) Education and training

68. One of the most essential elements of technology transfer is education. Training courses are being implemented in the major space agencies to make employees more aware of the process of technology innovation and technology transfer. Education is equally important in industry, public research institutes and the general public. While those professionally involved in technology development at the various stages require knowledge of how to initiate a transfer (e.g. acquisition or promotion), those not part of that process need to be educated on the benefits of technology transfer. The most important group to be educated is that of decision makers and policy makers. For all groups, education and training are the means to bring about transfer of technology and related spin-offs.

(e) Financial mechanisms

69. The most obvious financial mechanism is funding in various forms. Direct government funding of fundamental research is an integral part of the "technology-push" approach to innovation. Various financial incentives can be used for innovators in the form of royalties, encouraging them to publicize and to market their technologies. Other financial mechanisms may include tax incentives for entrepreneurs and innovators, subsidies and financing on a liberal and competitive basis.

3. Legal issues associated with transfer of technology and spin-offs

70. The most important question related to technology transfer is the issue of intellectual property rights, as no efficient transfer can take place without a reasonable level of legal protection. It is pointless to transfer or license a technology to a recipient if competitors may copy the technology and begin marketing it before the recipient can. Before a technology is transferred, therefore, it must be protected. It may be protected in two ways, by patent or by trade secret. The reasons for choosing the trade secret approach are twofold: firstly, not all technologies can be patented and, secondly, for a technology with a short lifetime, it might be cheaper to keep the invention secret. However, the patent is the most common form of protecting a technology.

71. Three conditions generally have to be met in order to obtain a patent: the invention must be new, useful and not obvious. Although conditions are very similar worldwide, two administrative systems coexist for the granting of the patent: the "first-to-file" principle, common in most industrialized countries, and the "first-to-invent" principle used in the United States of America. The patent grants monopoly rights for the exploitation of an invention within a certain time limit. On the other hand, the disadvantage of the patent is that it is expensive to obtain and to maintain, which are inherent obstacles to successful legal protection and thus

to technology transfers. However, the trend set by the Agreement on Trade-Related Intellectual Property Rights, Including Trade in Counterfeit Goods of the General Agreement on Tariffs and Trade, which established a provisionary patent application system, raises certain expectations in that respect.

72. Once the invention has been patented and the candidate transferee has been found, the appropriate form of licensing agreement must be chosen. Depending on the market situation and the business goals of the parties involved in the transaction, there are a wide range of licensing provisions (exclusive or non-exclusive licence, territorial, time or field-of-use restrictions, etc.) that will influence the relationships between the licensor and the licensee.

73. Another controversial issue affecting the international cooperation in transfer of technology and spin-offs is the practice of using bilateral or multilateral agreements instead of appropriate international treaties, while such agreements do not always match the related treaties. Some countries, including developing ones, believe that such an approach would make the international transfer process faster and more flexible.

IV. APPRAISAL

74. Since UNISPACE 82, the commercialization of space activities has become an irreversible and expanding process. The new political and economic environment has resulted in shifting the space industry's resources towards commercial opportunities. The industry is continuing its evolution from a government-driven, project-defined industry to one in which Governments play a lesser role and market forces predominantly dictate growth.

75. This process allows both industrialized and developing countries to benefit from such opportunities through strengthening economies, new market developments, job creation, educational opportunities and a higher standard of living. For developing countries, the commercial use of space technologies may also provide new opportunities for catching up with the industrialized countries. To maintain that momentum, it is extremely important that a collaborative environment is established and encouraged between government and industry, between science and the marketplace and between the industrialized and the developing countries.

76. When considering the numerous beneficial applications of technologies derived from space that can address the global needs expressed by society (environmental concerns, monitoring of mega-cities, increasing needs of security, etc.), it may be observed that space has a great potential to offer, in association with other sectors, to contribute to global solutions.

Distr.
LIMITED

A/CONF.184/BP/8
27 May 1998

ORIGINAL: ENGLISH

THIRD UNITED NATIONS CONFERENCE
ON THE EXPLORATION AND PEACEFUL USES OF OUTER SPACE

INFORMATION SYSTEMS FOR RESEARCH AND APPLICATIONS
(with emphasis on global environmental issues)

Background paper 8

The full list of the background papers:

1. The Earth and its environment in space
2. Disaster prediction, warning and mitigation
3. Management of Earth resources
4. Satellite navigation and location systems
5. Space communications and applications
6. Basic space science and microgravity research and their benefits
7. Commercial aspects of space exploration, including spin-off benefits
8. Information systems for research and applications
9. Small satellite missions
10. Education and training in space science and technology
11. Economic and societal benefits
12. Promotion of international cooperation

V.98-53895 (E)

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PREFACE

The General Assembly, in its resolution 52/56, agreed that the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) should be convened at the United Nations Office at Vienna from 19 to 30 July 1999 as a special session of the Committee on the Peaceful Uses of Outer Space, open to all Member States of the United Nations.

The primary objectives of UNISPACE III will be:

(a) To promote effective means of using space technology to assist in the solution of problems of regional or global significance;

(b) To strengthen the capabilities of Member States, in particular developing countries, to use the applications of space research for economic and cultural development.

Other objectives of UNISPACE III will be as follows:

(a) To provide developing countries with opportunities to define their needs for space applications for development purposes;

(b) To consider ways of expediting the use of space applications by Member States to promote sustainable development;

(c) To address the various issues related to education, training and technical assistance in space science and technology;

(d) To provide a valuable forum for a critical evaluation of space activities and to increase awareness among the general public regarding the benefits of space technology;

(e) To strengthen international cooperation in the development and use of space technology and applications.

As one of the preparatory activities for UNISPACE III, the Office for Outer Space Affairs of the Secretariat has prepared a number of background papers to provide Member States participating in the Conference, as well as in the regional preparatory meetings, with information on the latest status and trends in the use of space-related technologies. The papers have been prepared on the basis of input provided by international organizations, space agencies and experts from all over the world. A set of 12 complementary background papers have been published and should be read collectively.

Member States, international organizations and space industries planning to attend UNISPACE III should consider the contents of the present paper, particularly in deciding on the composition of their delegation and in formulating contributions to the work of the Conference.

Sources and information provided by the World Meteorological Organization (WMO), the European Space Agency, the Centre national d'études spatiales (CNES) of France, the National Aeronautics and Space Administration (NASA) of the United States of America and the President of the International Society for Photogrammetry and Remote Sensing and review of the paper by experts from the Economic Commission for Africa, CNES, the Canadian Space Agency, the Indian Space Research Organization and the Department of Space of the Government of India, the National Institute of Aeronautics and Space (LAPAN) of Indonesia and NASA are gratefully acknowledged.

The assistance of M. J. Rycroft (International Space University, Strasbourg, France, and Cambridge University, United Kingdom of Great Britain and Northern Ireland) as technical editor of background papers 1 to 10 (A/CONF.184/BP/1-10) is gratefully acknowledged.

SUMMARY

Information systems are fundamental tools for dealing with Earth observation data and other inputs, handling and integrating them through appropriate algorithms and generating output in the forms that are most suited to the intended user group. Dedicated numerical models and geographic information systems (GIS) are the most common types of system, the former used largely for the analysis and prediction of weather, climate and ocean currents, and the latter being important for land mapping, cadastral applications or disaster monitoring, in particular at the local and regional levels.

An important asset of the systems is their data-handling capacity. Firstly, they take in data of different origin, content and format. Secondly, they offer to the operator wide flexibility in manipulating the data and displaying them in a user-appropriate form. Finally, they permit the integration of data into a value-added product, the information content of which is higher than that of the individual items of data and is customized to meet user needs. The power of such tools depends not only upon their technical characteristics but also upon the quality of the input data and on keeping the database up to date with new data. Earth observations from space provide a coherent, objective and regular source of input data for such information systems.

Information systems are therefore of value for monitoring purposes, for observing an event and for planning and prevention activities. They are valuable tools for both research work and application activities, and eventually in decision-making.

The present paper reviews information systems and their capabilities to address such critical issues as global change, desertification, biodiversity and deforestation, and the need for a global approach to research that is cognizant of the needs of developing countries. It also covers the types of information needed for applications and the means by which such information could be acquired.

I. GLOBAL ISSUES AND ASSOCIATED INFORMATION SYSTEMS

A. Philosophy

1. For the planet Earth, great strides have been made in identifying and communicating to the general public major global issues such as depletion of the stratospheric ozone, desertification, forest preservation, coastal changes, biological diversity, the El Niño phenomenon, the increasing greenhouse effect and global warming. International concern in that respect is reflected in many international agreements, including, for example, the United Nations Framework Convention on Climate Change, the Rio Declaration on Environment and Development, adopted by the United Nations Conference on Environment and Development, held at Rio de Janeiro from 3 to 14 June 1992, the United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa, the Convention on Biodiversity and the Montreal Protocol on Substances that Deplete the Ozone Layer.

2. Those issues have become familiar to the public at large, although people are often unaware or confused about the real impact of such phenomena on mankind and the Earth's environment. The complexity of the interactions among the components of the Earth's system, namely, land, ocean and atmosphere, and their reactions to a change of one (or more) physical or chemical conditions are indeed difficult to analyse. It is therefore often not easy to identify a long-term trend and to separate its natural component from a possible effect induced by human activities.

3. Various international projects, like those associated with the World Climate Research Programme or the International Geosphere-Biosphere Programme, are aimed at gaining a better understanding of those phenomena. The issue of the interactions at different scales, from global to regional to local, is another major subject of research.

4. In that respect, information systems are fundamental tools for ingesting Earth observation data and other inputs on such phenomena, handling and integrating them through appropriate algorithms and generating output products in the forms most suited to the intended user groups.

5. The accuracy of the performance of models and the skill of the people involved in the analysis of their outputs affect the type and quality of decisions that are made about the above issues at the various stages of intervention, namely, before (simulation and prevention), during (monitoring and emergency actions) and after (impact analysis, reduction and mitigation). This is true both with regard to planning activities and to situations involving a disaster or environmental emergency.

6. Currently, two main categories of tools are commonly used for such activities: numerical models and geographic information systems (GIS). The former are used mostly in weather, ocean and climate analyses and forecasts, where observation data are assimilated by the numerical models in the form of digitized geophysical parameter values and integrated into systems of equations describing the static, dynamic, thermodynamic or chemical systems. First the "analysis", or description of the current status, is generated and then the forecast is derived by running the model forward in time through a suitable propagation model.

7. GIS are dedicated systems used primarily to achieve a comprehensive description of the environment and its territorial characteristics, generally on a local or regional scale. Inputs comprise a variety of digitized parameters describing the different aspects of an area: administrative borders, natural features like rivers and lakes, vegetation, topographic features, public transport elements such as roads and railways, pedological information, human settlements, geological patterns and so on. The merging of those elements together with the use of colours provide composite results, generally in the form of maps, which are the most readily understood means of visualizing the information related to the territory.

8. An important asset of information systems is their data-handling capacity. Firstly, they accept data of different origin, content and format. Secondly, they offer the operator great flexibility in manipulating the data, merging them and displaying them in a user-appropriate form. Finally, they permit the integration of data into a value-added product, whose information content is much greater than that of the source data and which can be customized to meet the user's requirements. The power of such tools depends not only on their technical characteristics but also on the quality of input data, in particular on the "age" of such data. Such systems are therefore built to allow for the continual updating of their databases.

9. Information systems are of great value in monitoring specific situations, observing an event or a situation and building a long-term series in order to detect possible changes, as well as to assist planning and prevention activities. The analytical capabilities of some of the systems (such as spatial decision support systems) to manipulate and transform interactively data that represent models of the real world and to build and explore different scenarios make them extremely valuable as major tools for both research work and application activities, as well as for decision-making.

B. Examples of information systems

10. In the above context, Earth observation from space provides a coherent, objective and regular source of input data for information systems. Data from meteorological and oceanographic satellites feed the meteo-climatic models globally, on all scales. Images taken around the world from high-resolution satellites provide accurate and updated data to GIS, in particular for the monitoring of large territories.

11. As observation systems mature, efforts have been made in many countries by the space agencies and organizations concerned to develop national information and data-management systems addressing global issues. Those systems are extremely valuable multidisciplinary research tools available internationally for scientists, educators, researchers or the general public from all over the world. Some examples of such systems include the multimission user information services of the European Space Agency (ESA), where users can review on-line acquired satellite data, the Data Base of the World Meteorological Organization (WMO), the Information Locator System of the Committee on Earth Observation Satellites (CEOS) and the European Union's Centre for Earth Observation.

12. In India, the Indian Space Research Organization (ISRO) has initiated a national programme, establishing a Natural Resources Information System (NRIS), which is a three-tiered, hierarchically networked GIS database for natural resource management, sustainable development at the local level, monitoring the environment and supporting the decision-making process in different sectors. With integrated Earth observation data, map information and non-spatial developmental information inputs, the system is intended to provide a basis for developmental planning and decision-making. Similarly, the National Informatics Centre in India has set up a country-wide computer network that links all the districts in the country to state and regional centres and to the central hub. Tabular databases on developmental issues in every district are available through the network, thus making it an "intranet" for sustainable development activities.

13. In the United States of America, the National Aeronautics and Space Administration (NASA) has established the Earth Observing System Data and Information System (EOSDIS), which is a comprehensive data and information system developed under the Mission to Planet Earth programme (now the Earth System Science Programme). EOSDIS manages data from NASA's past and current Earth science research satellites and field measurement programmes, and provides data archive, distribution and information management services.

14. Another United States agency, the National Oceanic and Atmospheric Administration (NOAA), runs the Environmental Services Data Directory (ESDD), which allows users to search for publicly available environmental data held by public and private sources throughout the world. Data sources include descriptions related to climatology, meteorology, ecology, pollution, geology, oceanography and remote-sensing satellites.

The search pages of ESDD on the WorldWide Web connect separate databases that together contain over 8,000 data set descriptions. At present, ESDD consists of eight distributed databases, including the National Climatic Data Center, the National Oceanographic Data Center, the National Geophysical Data Center, the National Snow and Ice Data Center, the National Environmental Data Referral Service, historical data sets at NOAA libraries (the Library and Information Services Division and the Geophysical Fluid Dynamics Laboratory) and the National Marine Fisheries Service database.

15. In Japan, the National Space Development Agency (NASDA) and the Science and Technology Agency have initiated the Global Research Network System project at the Earth Observation Research Center. The purpose of the project is to conduct research on collecting satellite, ocean and ground observation data, developing data-processing algorithms and preparing global data sets for hydrology, vegetation, desertification and oceanology studies, as well as to promote international research projects focusing on global issues.

16. In France, Spot Image's Device to Access and Look at Spot Inventory (DALI) system contains meta-data for all the Système pour l'observation de la Terre (SPOT) satellite scenes that have been received by the Toulouse and Kiruna stations since the launch of SPOT 1 (in February 1986) and by most of the SPOT direct receiving stations all around the world. In addition, it holds quick looks, available for browsing purposes, of all the SPOT scenes received at the Toulouse and Kiruna stations since 1991. In 1995, some of the direct receiving stations started delivering quick looks to DALI, on top of meta-data. The connection to the system can be made through the Internet using the DALI WorldWide Web Access.

17. Space technology provides an essential contribution to improving the overall performance of information systems, not only by providing Earth observation data, but also by supporting the data flow worldwide through space communication systems, both in transferring input data and in delivering the output information.

18. The progress in technology has made advanced tools commercially available, both hardware and software packages, which respond to the current needs and requirements of the above-mentioned operations. The evolution of the market will make it possible to upgrade those tools as required.

II. INFORMATION NEEDS AND ISSUES

A. Overview

19. An important step in solving problems of global and regional significance is to identify the issues relevant to major problems and concerns such as those mentioned above in which space technology could contribute to the understanding and solution of those problems. A common issue for all such problems is the need to have a coordinated means to acquire necessary data in a timely manner for monitoring, analysing and modelling the environment of Earth.

20. International meetings of experts, including, for example, the International Symposium on Core Data Needs for Environmental Assessment and Sustainable Development Strategies, have led to the identification of 10 categories of data that are common input to many existing information systems addressing global issues. They are as follows: air quality; climatology; demographics; economy; hydrology; infrastructures; land use and land cover; soils; topography; and water quality. Many of the categories of data reflect "transboundary" processes and require regional or global cooperation to ensure that the appropriate data sets are produced.

21. For most of the research and application needs related to environmental issues, the sources of information are the same, namely, field observations, ground measurements, remote-sensing data taken by airborne and space-borne sensors, ancillary inputs from archives and databases and additional information from experience and from statistics. However, although many data products are being created by government, university and

other research groups, the products are often difficult to find, fragmented and poorly documented, or they are unavailable in a suitable medium or in an easily understandable form.

22. Four specific considerations should be taken into account when starting an application:

(a) User requirements must be clearly defined from the very beginning;

(b) Integration of data from the various sources that can support the information requirements of the application should be considered;

(c) Use should be made of the experience gathered by others and, when possible, a regional joint endeavour should be sought;

(d) Data purchase/access must be considered at the project definition stage.

When discussing the applications of information systems for the benefit of human developments, a key issue to be considered is continuity, with respect to both data and services. The timely availability of information and its continuity are a prerequisite to enabling a sound decision to be made. This is true not only in the case of the occurrence of a disaster, but also when a strategic plan has to be set up and approved. This means that the source of the data must provide them at the right moment and with the right frequency of repetition. The main problem of the Earth observation space systems currently operational is the low revisiting rate: the user has to wait several days or, more often, weeks before the satellite again passes over the same place with the same viewing geometry.

23. The future of space-based remote sensing for operational monitoring of the territory, environment and disasters is therefore moving towards constellations of satellites able to ensure the high revisiting rate needed by the applications that support sustainable development studies.

B. Important issues

24. Several other issues that should be taken into consideration, in particular in addressing the global problems that require at least regional cooperation, include cross-calibration of satellite sensors used over time and across different instruments to monitor the same geophysical parameter; ongoing international agreements to share near real-time data products to produce secondary products; and lack of, or the lack of knowledge on, *in situ* validation data in every corner of the world.

25. Another very important issue is the need for education and training. Without an adequate transfer of know-how from developed to developing countries and institutions it is almost impossible to conceive of sustainable development. All levels of training need to be considered and assured for technical specialists, data interpreters, students and professors, decision makers and project managers. Furthermore, on-the-job training and training follow-up activities are extremely necessary.

26. The translation of data into information for political decision makers to use is another crucial issue. The global problems mentioned above require decision-making at all levels of government. For example, land degradation problems can sometimes be handled locally by zoning boards, whereas decisions to combat ozone depletion and greenhouse gas emissions require international agreements and, perhaps, even legally binding commitments. Government leaders can make the commitments for their respective countries, but it is individuals working at the local and provincial levels who must understand the criticality of the situation and influence the leadership at those levels.

27. Therefore, in addition to collecting and preparing geophysical data for monitoring purposes and scientific analyses, the information must extend beyond the scientific community and be made available in a properly

interpretable form for individuals and decision makers at the local, state, province and country levels. However, to achieve the full potential of information systems for applications in decision-making processes, the required data sets should be built up in a systematic and integrated manner.

28. In this context, the availability of clear and up-to-date information on technical issues and application results is essential to derive the full benefit from the use of information systems addressing global problems. Worldwide exchanges of information and the regular participation of researchers and decision makers in thematic workshops and conferences are also extremely important, together with appropriate access to the international computer and electronic mail (e-mail) networks and the Internet, and the link to global information infrastructures.

29. Another important issue concerns the protection of intellectual property rights. As various new information systems have been developed, this issue has become one of the most debated problems, as reflected in the discussions on international actions to ensure world protection of intellectual property rights for databases. Various legislative initiatives have been proposed in that regard. The European Communities have adopted a directive on databases that could greatly increase the protection of intellectual property rights of database creators and vendors in both the private and the public sectors. Similar legislative initiatives were introduced in both the United States Congress and the World Intellectual Property Organization. Although neither of the proposals was adopted, the legal changes that have been enacted in Europe and that are still being vigorously promoted in the United States and elsewhere have a number of attributes that could severely restrict data exchange, access and use by researchers, educators and other public interest users.

III. ECONOMIC AND SOCIAL BENEFITS*

30. The main economic and social benefits deriving from the use of information systems supported by space technology can be summarized as follows (not necessarily in order of priority):

(a) Increased understanding among policy makers, researchers and the general public of the interactions between different environmental issues, as well as between the environment and development;

(b) More accurate and integrated assessment of the overall environmental situation, permitting more pertinent decisions to be made and minimizing the waste of resources and the duplication of effort;

(c) Availability of detailed information over large areas, permitting implementation of global actions;

(d) Transfer of know-how, expertise and knowledge from industrialized to developing countries, as well as development of educational and training capabilities at the local level;

(e) Increased regional and international cooperation through joint projects and data sharing;

(f) Development of new technologies, resulting from scientific research on preventing, mitigating or adapting to the effects of global changes, which are useful for:

(i) Reducing energy consumption through conservation and energy efficiency;

(ii) Promoting the use of solar and renewable energy sources that reduce the amount of greenhouse gases released into the atmosphere;

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*A detailed review of economic and social benefits is given in background paper 11, "Economic and societal benefits" (A/CONF.184/BP/11).

(iii) Developing replacements for chlorofluorocarbons and other ozone-depleting substances that exhibit a significantly reduced potential for depleting stratospheric ozone;

(iv) Promoting the conservation of forest resources that help to reduce the amount of carbon dioxide in the atmosphere;

(v) Assisting developing countries in ecological pest management practices and in the proper use of agricultural and industrial chemicals;

(vi) Promoting recycling of pollutants in order to reduce the volume of waste that must be disposed of, thus decreasing energy use and greenhouse gas emissions;

(g) Development of reliable telecommunications infrastructures, which are essential for accurate and timely communications among data centres to transfer remote-sensing and other inputs needed by information systems and to disseminate the information generated by those systems.

IV. PROMOTION OF INTERNATIONAL COOPERATION*

A. Prerequisites

31. Satellite systems may act as bridges between countries at different levels of development, those levels not necessarily being related to the degree of industrialization of the countries involved.

32. In general, international cooperation encourages the initiation and domestic support of a project and provides a complement to national technical or material resources. However, three basic prerequisites need to exist at the national level for the successful implementation of a project and related developments, the local institutional commitment, the national investment and the local availability of skilled people and proper infrastructure, to ensure a proper transfer of know-how and technology, in particular in the domain of information systems.

33. The areas in which cooperation proves most effective include education (both in the form of stimulation of interest for decision makers and of specific training for technical specialists, students and teachers), technical assistance (in ground infrastructure, data processing, application work, planning, purchasing, operating and maintaining facilities), legal assistance (access fees, copyright and intellectual property rights), provision of hardware and software tools, data (provision of basic data sets to start working with or to demonstrate the feasibility of an application), meetings (creating venue opportunities in order to favour cross-fertilization between developing countries and industrialized countries) and provision of information (through contacts, documentation, e-mail conferencing and computer networks links).

34. Opportunities occur most frequently through application projects, either by joining existing projects or by creating new ones, in both cases looking for regional or international partnerships, which facilitate sponsorship by national and/or international institutions.

B. International programmes

35. A number of international initiatives are being carried out to address global environmental issues, including such programmes as the International Geosphere-Biosphere Programme, the Mission to Planet Earth

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*A detailed review of international cooperation is given in background paper 12, "Promotion of international cooperation" (A/CONF.184/BP/12).

programme, and the World Climate Research Programme, which is a part of the World Climate Programme, and the International Human Dimensions Programme of Global Environmental Change.

36. Three global observing systems, comprising both ground- and space-based observations data, have also been established: the Global Climate Observing System, established by the United Nations Environment Programme (UNEP); the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO), WMO and the International Council of Scientific Unions (ICSU); the Global Ocean Observing System, being developed by UNEP, IOC/UNESCO, WMO and ICSU; and the Global Terrestrial Observing System, set up by UNEP, the Food and Agriculture Organization of the United Nations, UNESCO, WMO and ICSU.

37. In the area of international cooperation in data access and management, several information systems have been developed by various international projects and programmes in order to provide the global scientific community with on-line access to data. One of the most successful activities in the field has revolved around CEOS. At present 11 countries host mirror information sites that offer over 5,000 data set descriptions from around the world, including from developing nations, through the CEOS International Directory Network. Two of the host sites are associated with UNEP (in Geneva and Nairobi).

38. The CEOS International Directory Network has been developed as an international effort to assist researchers in locating information on available data sets. The Network is sponsored by the Access Subgroup of the Committee on Earth Observation Satellites as a service to both the Earth and space science communities. It provides open on-line access to information on worldwide scientific data, including Earth sciences (geosciences, satellite remote sensing and hydrospheric, biospheric and atmospheric sciences), space physics, solar physics, planetary science and astronomy and astrophysics. The Network describes data held by university departments, government agencies and other organizations.

39. The International Geosphere-Biosphere Programme Data and Information System is a system devoted to understanding the data needs of the core projects of the Programme and to helping to ensure that those needs can be met. This involves such tasks as liaison with data holders internationally, providing documents where gaps exist and providing information on available and useful data standards from relevant organizations.

C. The Global Resource Information Database of the United Nations Environment Programme

40. The UNEP Global Resource Information Database (GRID) is a worldwide network of environmental data centres that was established to provide the global community with timely and reliable geo-referenced information and access to a unique international GIS service, with a view to addressing environmental issues at the global, regional and national levels in order to bridge the gap between scientific understanding of Earth processes and sound management of the environment.

41. The long-term objectives of GRID are as follows: (a) to enhance the availability and open exchange of global, regional and national geo-referenced environmental data sets, in digital and other formats; (b) to provide United Nations and other governmental bodies with access to improved environmental information and data-management technologies; and (c) to enable all countries and regions of the world to make use of GRID-compatible technology for resource management, environmental assessment, state-of-environment reporting and informed decision-making.

42. GRID works in a cooperative manner through 13 centres worldwide, each with its own responsibility in respect to both geographical data coverage and projects/services offered to users. Thus, for example, within the GRID network, the GRID-Geneva node has specific responsibility for the acquisition, documentation, archiving and dissemination of global and European digital, geo-referenced environmental data sets. It also specializes in data preparation and value-adding, database development, data search and provision through the Internet and WorldWide Web, hardware/software expertise and networking with partner agencies in general.

43. Another node, the GRID-Sioux Falls centre in the United States was set up to help nations attain sustainable development by making remotely sensed images and other spatial information available, as well as to develop methods for using that information to support models of population and the environment. GRID-Sioux Falls provides access to the extensive data archive of satellite imagery housed at the Earth Resources Observation System (EROS) Data Center of the United States Geological Survey. The primary database development activities are land cover characteristics, digital elevation mapping and the analysis of environmental change.

44. In addition, GRID-Sioux Falls, in cooperation with the EROS Data Center, is developing a geospatial data clearing house capability for the UNEP Caribbean Regional Coordinating Unit (CAR/RCU) office in Kingston as a part of the Environmental Information System project of the Caribbean Environment Programme, funded jointly by the United Nations and the Inter-American Development Bank. The goal of the project is to strengthen the information systems for the management of marine and coastal resources in the Caribbean region. This is being pursued through the development of information systems as tools for use in natural resource management and by the inter- and intra-regional exchange of expertise on natural resource management. Regional clearing house nodes will initially be established in designated environmental agencies in six countries: Barbados, Dominican Republic, Jamaica, Nicaragua, Trinidad and Tobago and Venezuela. Eventually, expansion is expected to include all 35 nations of the wider Caribbean region.

D. Other projects

45. The Inter-American Geospatial Data Network has been established to promote the use of computer network, primarily the Internet, capabilities in the Western hemisphere for electronic access to information describing the existence and availability of geospatial data. It is a project of the United States Agency for International Development, in partnership with the United States Geological Survey, designed to enhance information infrastructures as requested by the Summit of the Americas in December 1994. The initial collaborators have important collections of geospatial data for sites throughout the Americas, and are located in the United States, Brazil and Central America.

46. The global observation information network has been implemented as a cooperative effort between the United States and Japan to strengthen cooperation in Earth observation information networks, involving both satellite and *in situ* data. Other cooperative efforts in information systems development, data access and management include the Earth Observing System—Data and Information System project, the Global Land Information System and the CEOS Information Locator System.

47. Adequate and effective access to the data is a prerequisite for the successful use of information systems and this is impossible without modern methods of telecommunication. In order to facilitate the global exchange of environmental information vital for an understanding of urgent local and global environmental problems and information systems, a number of ESA member States have jointly supported the development of a satellite communications system for UNEP.

48. The Mercure system comprises 16 Earth stations serving two sub-networks. It provides UNEP with modern global telecommunications capabilities for the fast transfer of large volumes of environmental data, such as those representing detailed images of the Earth acquired from environmental satellites, and real-time video teleconferences between UNEP centres, as well as for handling Internet-type data traffic. The Mercure system has also been integrated into the UNEP global environment information network, UNEPnet.

49. The initial Mercure system is only the core of a much larger network. Several UNEP member States have indicated that they intend to acquire Mercure stations, while Norway is already providing facilities in Arendal, south of Oslo, for the administration of UNEPnet, including Mercure, and has provided the resources for the installation of a ground station there.

V. SOME SELECTED ISSUES OF INTEREST TO MEMBER STATES, IN PARTICULAR DEVELOPING COUNTRIES

50. Information systems are extremely powerful and effective tools for research and applications addressing global environmental issues. The use of those systems also makes an important contribution to sustainable development programmes in a number of ways, including: (a) allowing the implementation of an improved policy- and decision-making process based on timely and accurate data provided through modern technology; (b) building and strengthening institutional capabilities and developing human resources; and (c) making available a set of planning tools and techniques for improved natural resource management, environmental monitoring, sustainable development and disaster reduction, preparedness and management.

51. The target beneficiaries of activities associated with the use of information systems are the participating Governments and the relevant national/regional institutions; the decision makers and programme managers and operators; the technical, managerial and administrative personnel involved in the identification and the implementation of programme and project activities; the communities directly affected; individuals and end-users of programme- and project-related activities; and private companies.

52. However, to achieve the full potential of information systems for applications in support of sustainable development, a number of key issues should be considered. These include:

(a) Clear definition of user needs and requirements;

(b) Appropriate access to data and services;

(c) Inventory of all available data and information pertaining to the environment;

(d) Continuity of data and services;

(e) Development of standard meta-data formats for information exchange;

(f) Identification of *in situ* data available;

(g) Availability of capabilities in developing countries to establish information systems;

(h) Necessity to build required data sets in a systematic and integrated manner;

(i) Adequate access to telecommunications and computer networks ensuring the ability to reach remote data centres and information systems;

(j) Integration of national information systems into national information infrastructures and eventually into the global information infrastructure;

(k) Appropriate education, training and transfer of know-how;

(l) The impact of the protection of intellectual property rights, security measures and restricted access to databases on international information exchange;

(m) Frameworks for regional and international cooperation.

53. Another issue that may require the attention of developing countries is the support of national commercial information services and value-added companies operating in the area of remote-sensing data products and

services, thematic information for specific applications and the development of, or supplying data for, information systems, especially GIS. The growth of such companies in number and experience is certainly an asset for the sustainable development of a country.

54. Business opportunities exist in the various areas related to the design, development, integration, validation and operations (data distribution and applications and generation of thematic information) of remote-sensing and information systems. Companies can also look for continuous and recurring business to capitalize on investments (systematic provision of data, information, services and support). In particular, value-added companies could seek opportunities for joint ventures, participating in international projects to develop their expertise and to become known.